Biological Conservation 184 (2015) 365–379

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Review

Biological effects, conservation potential, and research priorities of shark diving tourism

Austin J. Gallagher[a,b,c,*], Gabriel M.S. Vianna[d,e], Yannis P. Papastamatiou[f], Catherine Macdonald[a], Tristan L. Guttridge[g,h], Neil Hammerschlag[a,c]

[a] Leonard and Jayne Abess Center for Ecosystem Science and Policy, University of Miami, Coral Gables, FL, USA
[b] Beneath the Waves Incorporated, Syracuse, NY, USA
[c] Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL, USA
[d] School of Animal Biology and Oceans Institute, The University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, Australia
[e] Australian Institute of Marine Science, The UWA Oceans Institute (MO96), 35 Stirling Hwy, Crawley, WA 6009, Australia
[f] School of Biology, University of St Andrews, St Andrews, Fife KY16 8LB, Scotland, UK
[g] Earth and Ocean Sciences, Cardiff University, Cardiff CF10 3XQ, Wales, UK
[h] Bimini Biological Field Station, 15 Elizabeth Drive, South Bimini, Bahamas

A R T I C L E I N F O

Article history:
Received 1 December 2014
Received in revised form 7 February 2015
Accepted 8 February 2015

Keywords:
Wildlife
Tourism
Charismatic species
Predator
Human impacts
Provisioning

A B S T R A C T

Shark diving tourism is a burgeoning, global industry. The growing perception that sharks can be worth more alive for tourism than dead in a fish market has become one of the leading contemporary arguments for shark conservation. However, there still exists concern that many aspects of shark-related tourism (e.g., provisioning) may alter natural behaviors and foraging areas, as well as pose a threat to humans by associating people with food. These concerns are largely driven by the previously limited scientific knowledge regarding the effects of shark diving tourism on shark biology, the marine environment and human interactions. Here we review and summarize previous research in these areas and evaluate the potential effects of dive tourism on shark behavior, ecology and subsequent human dimensions. To assist the development of future research, we provide a set of research questions. Taken together, we conclude that under the right conditions and if done in a precautionary, responsible manner, shark diving can provide a net conservation benefit (i.e., garnering of protective measures, raising awareness, instilling a conservation ethic) for a handful of species.

Contents

* Corresponding author at: Leonard and Jayne Abess Center for Ecosystem Science and Policy, University of Miami, Coral Gables, FL, USA. Tel.: +1 (305) 421 4356; fax: +1 (305) 421 4675.

E-mail address: gallagher.austin@gmail.com (A.J. Gallagher).

http://dx.doi.org/10.1016/j.biocon.2015.02.007
0006-3207/

1. Introduction

As humans continue to exploit natural resources, driving species population declines and biodiversity loss, the non-consumptive values of nature associated with tourism have become increasingly important (Davies, 1990; Duffus and Dearden, 1990). This type of ecological or natural tourism, often termed 'ecotourism,' is one of the fastest growing sectors of the tourism industry worldwide (Wearing and Neil, 1999). According to the World Tourism Organization (UNWTO), "ecotourism" is broadly defined as activities in which tourists observe and appreciate nature that minimize impacts on the natural and cultural environment and support the maintenance of natural areas and host communities (UNWTO, 2002). Additionally, these activities should contain educational features and be generally organized by small, locally-owned businesses. Species in their natural settings hold significant aesthetic and economic values, and wildlife viewing is one of the most profitable and popular forms of ecotourism worldwide (Kruger, 2005).

Charismatic animals tend to be the major attractions in the wildlife viewing sectors, and are commonly used as flagships for global conservation efforts (Zacharias and Roff, 2001). Shark diving tourism is a growing, worldwide industry focused on viewing sharks underwater by either snorkeling or scuba diving (e.g., Gallagher and Hammerschlag, 2011). Shark diving tourism is highly diverse in terms of species, cultures, and regulations. The industry is estimated to cater to more than half of a million participants annually, distributed in approximately 85 countries (Cisneros-Montemayor et al., 2013). Shark diving operations can generate significant revenues, benefiting select members of local communities and even national economies (e.g., Bahamas; Gallagher and Hammerschlag, 2011). Given that certain shark populations are experiencing significant population declines globally due to overfishing (e.g., Ferretti et al., 2010), the monetary benefits of shark diving have become a flag for shark conservation activism. In addition, the debate on this type of valuation has been rightfully discussed (see Catlin et al., 2013).

The majority of shark diving operations use an attractant (i.e., minced fish) to lure sharks in close proximity to tourists, where the animals are frequently offered food rewards to maintain their interest. Such practices have generated public and scientific concern as to the potential negative consequences for shark behavior or health, as well as for human safety. Accordingly, some coastal states or nations have banned shark diving activities involving food rewards (e.g., Florida and Hawaii, USA). Despite these concerns, scientific information regarding the industry and its effects is restricted to a few locations. In the last five years, there have been many studies covering a wide range of topics related to shark diving tourism, such as behavioral modifications or other effects on sharks, socio-economics, as well as legal and social issues (Table 1). However, this field of research has only begun to answer the many questions remaining regarding the biological, ecosystem, socio-economic, safety and conservation implications of this growing industry.

Despite the global nature and popularity of this industry, as well as the recent surge of research interest into assessing it, there are currently no conceptual frameworks for guiding empirical research, nor is there a set of science-based recommendations on how practices can be designed to promote conservation and sustainability while minimizing impacts. Instead, there seems to be a high degree of mistrust, doubt, misinformation in the media, and questioning of validity of data and results between studies and researchers, and an even greater amount of controversy surrounding certain practices and specific operators among the public and through social media (Authors, direct observation). Thus, a conceptual overview of the literature and issues surrounding shark diving tourism may be of great value to the scientific, policy, and public communities.

Here we provide a comprehensive and quantitative review of the research surrounding the shark diving tourism industry by analyzing trends and patterns in the literature, summarizing what is known from previous work, identifying critical knowledge gaps, and providing recommendations for future research. We also compare findings from the shark literature to other forms of wildlife viewing and tourism (where appropriate). We focus on five broad categories and their associated research priorities: behavior (learning, habitat use and movement), ecology and trophic interactions, animal welfare, human dimensions (safety, socio-economics, conservation and research, management), and practice (regulation, codes of conduct). To identify areas where future research can be directed to maximize benefit, we also provide a comprehensive set of questions that may serve as a road map for future studies.

While the terms "shark diving ecotourism" and "shark-diving tourism" are often used interchangeably in the literature, use of the word "ecotourism" implies ecologically sustainable practices which directly contribute to the maintenance of species, habitats, and local cultures (Valentine, 1993; UNWTO, 2002). Due to the wide range of operations and variation in practices and ethics, we refrain from using the word "ecotourism" in the remainder of our paper. Instead, we use the term "shark dive/diving tourism" throughout to describe the practice of tourists paying for in-water experiences with sharks in their natural habitat. Since the majority of shark diving operations worldwide use bait and attractant (Gallagher and Hammerschlag, 2011; see also references in Table 1), a large proportion of our discussion indeed focuses on diving operations in which sharks are "provisioned." We define "provisioning" as those activities where some type of attractant, bait, or food reward is offered for the tourism purposes of aggregating or positively reinforcing sharks to neutralize their aversion to humans (Orams, 2002; Knight, 2009; Fig. 1), although other activities which do not use provisioning are also mentioned (i.e., basking shark and whale shark tourism). We also impart that this paper does not argue or advocate for or against any activities related to shark diving tourism.

Table 1
Published shark diving tourism studies considered in the present review, up until and including 2014. An "X" denotes whether that particular subject area was a focal area of each study. *Denotes a rebuttal or response paper.

Count	References	Ocean	Primary shark species examined	Time frame evaluated	Biology/ habitat use	Ecology	Animal welfare	Socio-economics	User experience	Policy/ management	General/ overview
1	Davis et al. (1997)	Indian	Whale	<1 year			X	X	X		
2	Davis (1998)	Indian	Whale	2 years			X		X	X	
3	Topelko and Dearden (2005)	All	n/a	n/a							X
4	Dobson (2006)	Indian + Atlantic	n/a	n/a						X	
5	Rodríguez-Dowdell et al. (2007)	Pacific	Whale	n/a					X	X	
6	Quiros (2007)	Indian	Whale	2 years			X		X	X	
7	Laroche et al. (2007)	Indian	White	<1 year	X						
8	Rowat and Engelhardt (2007)	Indian	Whale	<1 year				X		X	
9	Mau (2008)	Indian	Whale	n/a						X	X
10	Jones et al. (2009)	Indian	Whale	<1 year				X	X		
11	Dicken and Hosking (2009)	Indian	Tiger	<1 year				X	X		
12	Meyer et al. (2009)	Pacific	Galapagos/ sandbar	4 years	X						
13	Smith et al. (2009)	Indian	Grey nurse	<1 year				X	X		
14	Pierce et al. (2010)	Indian	Whale	<1 year			X			X	
15	Brunnschweiler (2010)	Pacific	Bull	4 years				X			X
16	Clua et al. (2010) *Brunnschweiler and McKenzie (2010)	Pacific	Lemon	3.5 years	X						
17	Smith et al. (2010)	Indian	Grey nurse	<1 year	X		X			X	
18	Vignon et al. (2010)	Pacific	Lemon	2 years		X					
19	Catlin and Jones (2010)	Indian	Whale	<1 year			X	X	X		
20	Catlin et al. (2010a)	Indian	Whale	<1 year				X			
21	Catlin et al. (2010b)	Indian	Whale	<1 year				X	X		
22	Maljković and Côté (2011)	Atlantic	Caribbean reef	<2 years	X						
23	Gallagher and Hammerschlag (2011)	All	n/a	n/a				X			X
24	Brunnschweiler and Baensch (2011)	Pacific	Bull	7 years	X						
25	Clarke et al. (2011)	Indian	Silky	<2 years	X						
26	Fitzpatrick et al. (2011)	Indian	White-tip reef	<1 year	X						
27	Cubero-Pardo et al. (2011)	Pacific	Hammerhead	<1 year	X		X				
28	Barker et al. (2011a)	Indian	Grey nurse	<4 years	X		X				
29	Barker et al. (2011b)	Indian	Grey nurse	<4 years	X		X				
30	Clua et al. (2011)	Pacific	Lemon	<5 years				X			
31	Hammerschlag et al. (2012)	Atlantic	Tiger	<1 year	X	X					
32	Ziegler et al. (2012)	Atlantic	Whale	<1 year				X	X		
33	Catlin et al. (2012)	Indian	Whale	<1 year				X		X	
34	Vianna et al. (2012)	Pacific	Reef spp	<1 year				X			
35	Du Preez et al. (2012)	Indian	Tiger	<1 year				X			
36	Bruce and Bradford (2013)	Indian	White	<2 years	X						
37	Brunnschweiler and Barnett (2013)	Pacific	Bull	8 years	X						
38	Huveneers et al. (2013)	Indian	White	<2 years	X						
39	Techera and Klein (2013)	Indian	n/a	n/a						X	
40	Bradford and Robbins (2013)	Indian	White	>10 years				X			
41	Clarke et al. (2013)	Indian	Silky	>10 years	X						
42	Cisneros-Montemayor et al. (2013) *Brunnschweiler and Ward-Paige (2014)	All	n/a	n/a				X			X
43	Smith et al. (2014)	Indian	Grey nurse	<2 years			X	X	X	X	
44	Dicken (2014)	Indian	Grey nurse	<7 years				X			
45	Cagua et al. (2014)	Indian	Whale	<1 year				X			
46	Anderson et al. (2014)	Indian	Whale	<5 years				X			
47	Apps et al. (2014)	Indian	Grey nurse	<1 year				X	X		

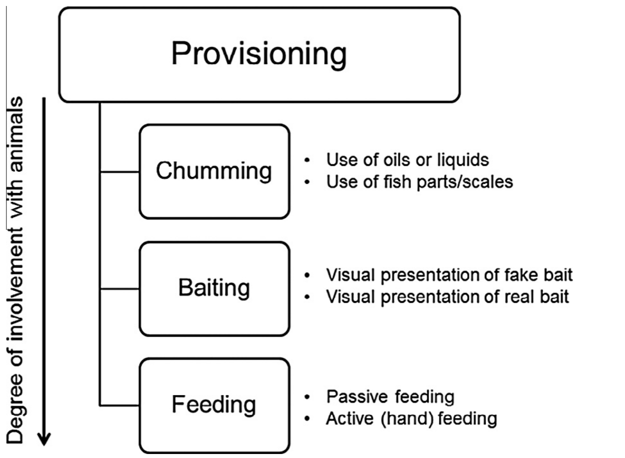

Fig. 1. Multi-level hierarchy defining the various types of provisioning used in most shark diving tourism operations and their relative degree of involvement with the animals (moving from low [top] to high [bottom]).

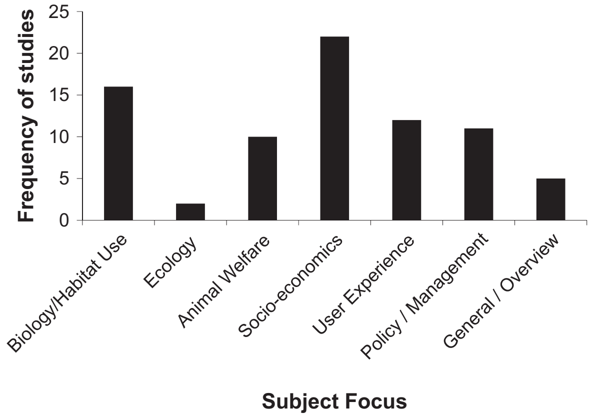

Fig. 2. Frequency of studies covering various focal research areas among the 47 published studies on shark diving tourism.

2. Methods and results

Peer-reviewed publications were selected from the Science Citation Index Database (Web of Science) and the Aquatic Science and Fisheries Abstracts (ASFA) as a secondary search using the title and keyword searches: 'marine tourism, 'shark diving tourism,' and 'shark ecotourism'. The Web of Science search generated papers that fell between the earliest records of the database (1945) up to January 2014. The more than 500 publications were filtered on two criteria: (1) the study must have been published in the primary literature and (2) sharks were the focal organism/system of the investigation. For example, several studies on marine tourism have mentioned or included 'sharks' as a component of various regional tourism industries; however, these were excluded from the analysis because 'sharks' were not the focus or target of the tourism being evaluated. Unpublished theses, conference proceedings, book chapters, and reports from the grey literature were excluded. Additional papers (including a handful appearing in 2014) were added from authors' personal libraries and literature cited sections from the list of relevant papers were surveyed until no further publications arose. The ASFA search generated 194 publications that were cross-referenced against those already compiled. This search did not turn up any new papers that met our criteria, suggesting that our literature coverage was comprehensive. Once the final list of original articles was compiled, we noted the following information from each: (a) year of publication, (b) primary ocean basin in which the study was conducted, (c) the primary shark species studied, and the (d) the time frame of the study in years. Lastly, we categorized each study into either one or multiple categories: biology and habitat use, ecology, animal welfare, socio-economics, user experience, policy/management, and general/overview.

Our review identified 47 original research articles published up until and including 2014 focusing on some aspect of the shark diving tourism industry (Table 1). The first study to explicitly focus on shark diving tourism in some way was Davis et al. (1997), an overview of the whale shark diving operations off Western Australia, which provided some of the first socio-economic data on the industry. Three studies provided a global view of certain aspects of the industry: Topelko and Dearden (2005) introduced shark diving tourism as a worldwide industry and was the first study to formally discuss shark diving tourism as a potential benefit for shark conservation; Gallagher and Hammerschlag (2011) provided the first global analysis and report of the shark diving industry and was among the first to formally discuss and compare tourism revenues to those earned via fishing; Cisneros-Montemayor et al. (2013) replicated a handful of the approaches already conducted by Gallagher and Hammerschlag (2011) and attempted to calculate the economic value of the entire industry. Of all articles (44, excluding the three papers which were considered 'global overviews'), approximately 68% (30 studies) occurred in the Indian Ocean, 23% (10 studies) in the Pacific Ocean, and ~9% in the Atlantic (4 studies, Table 1). The apparent lack of research in the Atlantic Ocean is surprising due to the scale of shark diving operations in the region, as well as the popularity of shark diving in the Bahamas alone (Gallagher and Hammerschlag, 2011). Forty studies were assessed as having evaluated a primary shark species, with the whale shark emerging as the most studied shark species (15 studies, 37.5% of all studies, Table 1). The grey nurse shark was the second most-studied primary species (7 studies, 17.5%, Table 1), whereas the other 45% of studies focused on a variety of species. That the whale shark dominates the literature is not surprising, as they are massive, slow-moving, and have had established tourism industries for decades in numerous locations worldwide (Gallagher and Hammerschlag, 2011, Table 1). White sharks have only been considered in 4 studies to date, whereas 'reef sharks' as a group have only been explicitly considered in two studies. This latter finding is surprising especially since research has shown that this group of sharks is the most prevalent in shark diving operations worldwide (Gallagher and Hammerschlag, 2011). Socio-economic analyses comprised the majority of studies, ~47%, whereas biological reporting and assays of habitat use (behavioral analyses) of sharks occurred in 34% of studies (Fig. 2, Table 1). Other subject foci such as the user experience (~26%), policy and management (23%), animal welfare (21%), general overviews (10%) and ecology (4%) were less widespread and covered in the literature (Fig. 2, Table 1). The number of relevant papers published annually started increasing in 2007, with the trend steepening from 2010 to present (Table 1). Based on these results, we identified 5 important themes/foci of research within the context of shark diving tourism and organized the rest of the manuscript to provide a succinct yet comprehensive summary of each focal topic while using these concepts to present a framework for future studies. We also recognize that certain topics (behavior, ecology, animal welfare, socio-economics) present a more substantive analysis and warrant a deeper discussion than others (conservation potential, community management, bites on humans, practice). We affirm that these differences are reflective of the existing body of available information and should be an indication of gaps for future research.

3. Behavior

3.1. Learning

The adaptive modification of behavior based on experience (learning) affects virtually every aspect of animal behavior from finding food and avoiding predators to meeting potential mates. It allows an animal to develop, within its lifetime, an adaptive response to a completely novel situation that has potentially never been encountered in the species' evolutionary past (Kawecki, 2010). Shark diving tourism creates scenarios with novel stimuli for the animals to react to; as such the ability to learn is central to this issue. Broadly, repeated exposure to stimuli creates the opportunity to learn via: (i) associative learning, which is the learning of an association or relationship between two events (e.g., operant and classical conditioning, observational learning); and (ii) non-associative learning, which is when learning occurs as the result of the presentation of a single stimulus (e.g., habituation and sensitization; Lieberman, 1990).

Sharks like many other animals use learning across behavioral processes (Guttridge et al., 2009; Schluessel, 2014). Early experiments using operant and classical conditioning paradigms identified that sharks could learn discriminative tasks as rapidly as other vertebrates, retain such information for long time periods and display comparable learning characteristics to mammals (e.g., Clark, 1963; Aronson et al., 1967). More recently, empirical studies have demonstrated that sharks are able to learn from each other and have memory windows varying from 12 h to a few days or even months (Guttridge and Brown, 2013; Kimber et al., 2014; Schluessel, 2014). Interestingly, researchers have found that sharks become increasingly more accurate and efficient at moving between key landscapes as they gain experience, providing strong evidence of memory (Papastamatiou et al., 2011). Clearly sharks exhibit cognitive abilities, and for animals exposed to provisioning tourism activities (Fig. 1), the opportunity to learn is further enhanced since the incentive is usually offered frequently and at specific times of day and locations. These activities have the potential to lead to the repeated use of artificial feeding sites, as well as sharks becoming 'conditioned' or 'conditioned to human interaction by food reinforcement,' as seen in other taxa such as cetaceans, reptiles and primates (Kamal et al., 1997; Walpole, 2001; Bejder et al., 2009).

Working with white sharks (*Carcharodon carcharias*) in South Africa, Johnson and Kock (2006) found that the 'speed of arrival' to a chumming boat was significantly reduced with increasing experience. Further along the same coast, Laroche et al. (2007) found that great white sharks receiving more rewards did not have a greater propensity to remain near the boat. Working in the Neptune Islands in Australia, Bruce and Bradford (2013) determined that increases in white shark numbers, visit duration and residency periods were concomitant with an increase in operator effort and regularity. Interestingly, on days when cage diving operations were not present, sharks still maintained these movement patterns aligning with the overall daily timing of cage diving operators. The authors suggested that this was indicative of a conditioned or anticipatory response by sharks to the provisioning at the site, although this may result from another natural stimulus such as seal (prey) behavior. Further it is important to note that comparisons were made between North and South Neptune Islands, Australia, where data from the South Island were limited and mainly based on one individual. Similarly, Brunnschweiler and Barnett (2013) working with bull sharks (*Carcharhinus leucas*) in Fiji found that sharks were attracted to the feeding site regardless of whether feeding was occurring, but remained present for longer periods of time (consecutive hours) when food stimulus was present.

These studies provide early evidence that sharks will exhibit some degree of conditioning and are able to learn during shark diving operations as a result of provisioning. Empirical studies on learning show that it is strongly influenced by the frequency and intensity of reinforcement and by the temporal and spatial contiguity of events (Rescorla, 2008), yet, in general most studies on shark provisioning tourism are either unable or do not to monitor the amount and frequency of food rewards that individual animals receive (but see Maljković and Côté, 2011). Without such information it is particularly difficult to interpret and assess the effects of conditioning on target animals and to identify the mechanisms underlying such behaviors (Bejder et al., 2009). Importantly, in some locations the actual feeding of sharks is prohibited, and these studies will also need to take into account the effects of chumming or berleying with or without reinforcement.

While it may be impractical to identify learning criteria for individual sharks exposed to provisioning on dives, there is a need to further explore what level of feeding is sufficient to generate a conditioned response (Tables 1 and 2). At this stage, few studies have related feeding frequency and quantity to behavior, space use and physiology, and this is further complicated by the effects of individual feeding history (i.e., motivation), bait quality, experience, memory retention, behavioral syndromes, presence of conspecifics or predators as well as environmental conditions (Huveneers et al., 2013). Clearly our understanding of shark learning as it relates to tourism is still in its infancy, and only through further research, including controlled learning experiments, can we inform the current debate regarding the effects of provisioning.

3.2. Habitat use and movement

Unnatural human-mediated changes in the quality, quantity and delivery of food to animals in the wild can promote substantive trade-offs in activity budgets, thus altering fundamental aspects of their behavior and dynamics within the ecosystem (Campbell-Smith et al., 2011). For example, wild populations of baboons (*Papio cynocephalus*) were shown to decrease their activity and home range by nearly 50% in response to varying levels of provisioning (Altmann and Muruthi, 1988). Research is beginning to define the spatial and temporal scales of these types of movements for sharks, the details of which are crucial to a nuanced examination of this issue among provisioned sharks (e.g., Huveneers et al., 2013).

Movements over large spatial and temporal scales are of particular concern as many species of shark perform seasonal migrations over thousands of kilometers, linked to key life-history phases (Domeier and Nasby-Lucas, 2013; Papastamatiou et al., 2013). It should also be noted that for the majority of studies described hereafter, movement and population studies were initiated *after* the establishment of tourist diving operations making it difficult to validate the cause of observed changes over time (Brunnschweiler and McKenzie, 2010; Bruce and Bradford, 2013), or the resolution suffers from a lack of proper, ecologically-relevant controls (i.e., large geographic distances, Hammerschlag et al., 2012). Overall residency periods for tiger sharks (*Galeocerdo cuvier*) did not differ between feeding and non-feeding sites in the Atlantic, and individuals still performed long range movements (Hammerschlag et al., 2012). In fact, the group of sharks that were exposed to provisioning in Hammerschlag et al. (2012) traveled longer distances (linked to natural foraging forays or reproduction). The seasonal changes in numbers of Galapagos (*Carcharhinus galapagensis*) and sandbar sharks (*Carcharhinus plumbeus*) at an offshore cage diving operation in Hawaii, demonstrated fluctuations that match the seasonal inshore–offshore migration patterns for these species (Meyer et al., 2009). As described earlier, the presence of cage operators has increased the residency periods of white

Table 2
Biological, ecological, and social science research needs for the field of shark diving tourism.

Category	Area of focus	Research question
Behavior	*Learning*	To what extent can sharks learn to associate human presence with food rewards?
		Can sharks learn patterns, behaviors, and tendencies from others at dive sites?
		Which mechanisms underlie conditioning to food rewards?
		What level of feeding is required to elicit a conditioned response?
	Habitat use and movement	What are the short term patterns of shark movement?
		What are the long term patterns of shark movement?
		Are species segregated by sex?
		What is the site fidelity to the diving site?
		Does provisioning affect shark diel patterns of activity?
	Human interaction	How does handling the animals affect their interactions with divers?
		Does provisioning lead to aggression within and among species?
		What are the impacts of baiting/chumming versus feeding?
		Does hand-feeding lead to dominance hierarchies?
		What influence do the operations have on energy expenditure or energy budgets?
Life history	*Age and growth*	Does human-supplemented feeding affect growth rates?
		Are species in reproductive modes at provisioning sites?
		How does human-supplemented feeding affect reproductive rates/modes?
		Are sex ratios altered by diving operations?
Ecology	*Trophic interactions*	Do trophic roles and foraging rates change with baiting and feeding?
		Are prey species released from predation risk at dive sites?
		What is the spatial scale of predation release?
		How does provisioning change the nutritional profiles of sharks?
		Are ontogenetic shifts in diet affected?
Social	*Socio-economics*	How much are tourists willing to pay to observe sharks in the wild?
		What is the value of shark diving?
		Will fishers realistically shift from exploitation to non-consumptive use?
		What are the employment opportunities for local peoples?
	Best practices	What are the preferences of divers?
		Do divers enjoy when trip leaders handle/manipulate sharks?
		What are the impacts of handling and manipulating sharks in the water?
		Is a universal or species/specific code of conduct appropriate?
	Cultural issues	Do locals receive compensation from operators?
		What are the attitudes of local cultures to the shark diving industry?
		What is the feasibility of implementing diving operations in under-developed areas?
		Do those who fished sharks actually receive compensation from switching to diving?
		How can economic incentives of the industry be used to substitute fishing practices?
	Safety	Do shark diving operations increase risk of shark bites?
		Does shark diving increase the rate of natural encounters between humans and sharks?
		Does shark diving increase interactions between fishers and sharks?
Conservation	*Biodiversity indices*	Are there differences in species richness compared to normal sites?
		Are there differences in species abundance compared to normal sites?
		What are the long term changes in community dynamics inside shark diving sites?
	Research	How can shark diving operations benefit research and policy?
		How can shark diving affect the sustainability of shark sanctuaries and MPAs?
		What percentage of shark diving operations exist within a marine reserve/protected area?
		Can shark diving operators function as enforcement for marine protected areas?
		Are sharks harvested or fished at/near diving sites?
Policy	*Legal*	What are the legal frameworks for shark diving practices?
		Are local, state-wide, or national shark diving regulations informed by science or opinion?
		How does shark tourism fit into local, regional, or national management plans for sharks?

sharks to the Neptune Islands, Australia, with residency periods of up to 92 days (Bruce and Bradford, 2013). It is important to note that the median residency of sharks in this study was 11 days, and sharks were detected performing their presumed normal westerly migration patterns (Bruce and Bradford, 2013).

Over shorter time periods (e.g., hours to days), shark viewing operations can potentially have a greater influence on movements and activity. Whitetip reef sharks (*Trianodon obesus*) are normally nocturnally active, but demonstrate increased levels of diurnal vertical activity when tourism operations are present (Fitzpatrick et al., 2011). Bull sharks in Fiji and silky sharks (*Carcharhinus falciformis*) in the Red Sea will visit reefs regardless of the presence or absence of baiting operations, although small-scale residency will increase when bait is available (Clarke et al., 2011; Brunnschweiler and Barnett, 2013). However, although silky sharks demonstrated particularly defined diel shifts on days when baiting occurs, they perform diel horizontal shifts naturally (Clarke et al., 2011). White sharks in Australia show an increased residence time within cage diving areas at fine spatial scales, swim at shallower depths when in proximity to cages with lower rates of movement and reduced horizontal range, and also modify diel patterns of behavior, although this might be expected since cages are most frequently placed at the surface (they are also deployed at depth, Huveneers et al., 2013; Bruce and Bradford, 2013).

Overall, these results show that the effects of shark diving tourism on movements and activity space are mixed and are likely species, operation and scale (time and space) specific. Based on the existing data for a few species, it appears that baited shark diving operations can change the localized or short term behavior of sharks in the area, but will likely not attract sharks across broad geographic areas (e.g. islands, or large reefs), influence migration, or prevent them from undergoing key life-history events (Meyer et al., 2009; Maljković and Côté, 2011; Hammerschlag et al., 2012). It should, however, be noted that it is possible for changes which appear relatively minor to significantly impact energy budgets and individual fitness (Fitzpatrick et al., 2011; Huveneers et al., 2013). Within almost all these studies, there were large individual differences in residence times, conditioning and foraging success. Recent work contributes to the notion that fishes can exhibit individual specialization resulting in differences in movement linked to intra-specific habitat or food preferences (Hammerschlag-Peyer and Layman, 2010; Matich et al., 2011). As such, future work on movements associated with shark-diving tourism should continue to examine both short and long term movements as well as focus on whether tourism impacts differ by sex or among individuals, and across patches of environmental variability. Further, research with sufficient experimental or natural controls is sorely needed in future work of this kind. It is also important that the effects of shark diving on shark movements go beyond just looking for relationships between that two, but rather trying to understand if and how such relationships can subsequently impact fitness, such as trade-offs in activity budgets.

It is worth considering that most shark diving operations do not randomly select shark diving sites; instead, they tend to take place amongst areas that already exhibit high shark abundance (Gallagher and Hammerschlag, 2011). Therefore, a given researcher's interpretations may be confounded and it could be thus difficult to quantify the extent to which provisioning tourism serves to aggregate individuals to a site or vice versa. For example, at Seal Island in South Africa, white shark tourism occurs at a location where sharks are actively patrolling seal rookeries in search of seal prey. Very little attraction (sound or bait) is required for the sharks to come by the boat (AJG and NH, direct observations), therefore it is important to define terms and use caution when interpreting results as such.

4. Ecology and trophic interactions

Changes in the feeding behaviors, abundance, and habitat use of large consumers can have consequences for community dynamics through trophic cascades (Estes et al., 1998). Although rarely considered, shark dive tourism has the potential to influence all three of the above aspects of animal biology and ecology.

Where shark provisioning occurs, consumption of the bait (which is essentially scavenging) could potentially result in sharks ceasing to hunt and feed on their normal prey, although this has not been documented yet. Under those conditions, a trophic cascade could result, in which prey species are released from predation pressure, potentially causing prey to increase resource foraging rates, with the risk of a subsequent cascade to other community members. Laroche et al. (2007) studied the effects of dive tourism attracting and provisioning on white sharks aggregating to hunt Cape fur seals (*Arctocephalus pusillus pusillus*) at a colony in South Africa. They found little to no impact of these activities on shark behavior and similarly no changes in seal movements during periods of shark diving. The authors concluded that moderate levels of dive tourism were unlikely to initiate trophic cascades at an ecosystem level. By monitoring the success rates of individual sharks taking offered bait and calculating energy intake rates, Maljković and Côté (2011) concluded that these successful individuals were unlikely to meet their metabolic needs with offered bait and that their natural predation rates are unlikely to be altered by provisioning. These results should not be extrapolated to other species or systems, however, and future work in this area is warranted.

It is also plausible that attracting and aggregating sharks from a distance to a dive site could intensify predation on local prey species and in turn reduce the predation pressure in previously occupied areas. Alternatively, if sharks already in the area of a tourism site are sufficiently fed, perhaps predation pressure will be significantly reduced on prey there, subsequently impacting trophic interactions at the site. Current evidence is not adequate to meaningfully address the question of shark dive tourism impacts on community ecology; however, this subject could be addressed through the establishment of long-term ecological and biodiversity monitoring at sites and will benefit from close collaboration with local operators (the benefits of which are discussed later).

Artificially aggregating large sharks at a small spatial scale (the diving site) could also impact nutrient dynamics through increased excretion, thus providing a concentrated source of limiting nutrients for primary producers (Allgeier et al., 2013). Nutrient exchanges by sharks among habitats has only recently been considered (Matich et al., 2011) and is an area that requires research attention as it relates to dive tourism.

The timing of migrations between foraging and reproductive areas in vertebrates can depend on metabolites and lipid reserves. For example, European eels (*Anguilla anguilla*) need a minimum threshold of body fat before they begin migrations to spawn (Larsson et al., 1990). It is unknown if and how supplemental feeding, in which the quality of bait may vary, can affect the timing and success of migratory behavior (which is likely driven by fatty acids in sharks (Gallagher et al., 2014). For example, could reproduction fail to occur if sharks are fed nutrient poor food items to satiation that do not meet the energetic and nutritional needs required for challenging life-history phases?

It is also worth considering that in the case of commercially important fishes and invertebrates consumed as seafood, attraction and aggregation at the shark dive site could make them disproportionately prone to exploitation. Moreover, it also remains relatively unknown whether any provisioning could alter the quality, condition and health of fishes collected and consumed from the dive site. However, Vignon et al. (2010) found that grouper and snapper species collected from inside dive locations where sharks were regularly fed contained significantly higher parasite loads when compared to control-site counterparts. The mechanism for this food-web transfer of parasites was thought to be due to higher excretion rates of provisioned-sharks (Vignon et al., 2010). Lastly, removals of other top consumers (i.e., piscivores such as groupers or snappers) for continued (e.g., daily) use as bait in shark diving tourism activities may also be another important but often overlooked issue at the local level.

5. Animal welfare

The term 'non-consumptive' as it relates to wildlife recreation is defined by Duffus and Dearden (1990) as "human recreational engagement with wildlife wherein the focal animal is not purposefully removed or permanently affected by the engagement". However, a growing body of work provides evidence that human presence during wildlife tourism can have sublethal physiological impacts on animals which can in turn impact important aspects of animal function such respiration, stress management, reproductive success, and body condition (e.g., McClung et al., 2004; Müllner et al., 2004; Bejder et al., 2006; Semeniuk et al., 2009). Indeed, many predators show measurable stress responses to human presence. Wolves have been found to exhibit increased physiological stress in response to the presence of snowmobiles (Creel et al., 2002); while the mere presence of hikers in wilderness areas without direct interaction is enough to elevate levels of fecal stress hormones in wildcats (Piñeiro et al., 2012). Lions display increased respiration and disturbance in the presence of humans (Hayward and Hayward, 2009) and cheetah hunting success is sharply diminished when tourist vehicles are present (Caro, 1994). There are many more examples from other taxa in the literature not discussed here due to spatial limitations, but they should be explored and consulted.

Table 3
Potential biological sublethal impacts on sharks exposed to various activities commonly associated with shark diving practices. The "Moderator" column is used to characterize the party most responsible for the outcome of each activity (operator, shark, or both).

Activity	Moderator	Potential sublethal impact
Shark collides with cages or watercraft	Shark and operator	Physical injury, disease, impaired locomotion, deformity
Shark is continuously put into tonic immobility	Operator	Equilibrium loss, impaired homeostasis
Shark is touched and manipulated	Operator	Physical injury, impaired locomotion and ecology
Shark is hand-fed	Operator	Decrease in natural predation success
Shark bites bait crates and chum devices	Shark	Impaired feeding, loss of foraging opportunities
Shark is chronically flashed by camera strobes	Operator	Physical injury, impaired vision and visual detection
Shark becomes crowded with conspecifics	Shark and operator	Shift in habitat use and timing of life-history events, injury
Shark is tricked into performing impressive behaviors	Shark and operator	Decreased energy for foraging and somatic growth
Sharks are displaced into new areas and habitats	Shark and operator	Increased territoriality, skewing of sex ratios, predation on conspecifics

Such sublethal impacts are rarely considered in shark diving tourism (Table 3), but a few studies provide evidence that they may exist. In one study, researchers demonstrated that approaching sharks more closely than 3 m caused resting sharks to increase their swimming speed and adjust their mode of respiration (Barker et al., 2011a,b). Similarly, whale sharks were likely to change swimming direction when confronted with swimmers in their paths or in close proximity, and displayed aversive behavior when touched (Quiros, 2007). Species can also become physically damaged through interactions: whale sharks exhibit scarring from collisions with boat propellers (Speed et al., 2008) as do certain white sharks which are wrangled into shark cages (Authors, direct observation, Fig. 3).

Some operators permit their staff and guests to engage in handling or manipulation of large predatory sharks (i.e., touching, grabbing, inverting; Shiffman, 2014a, b). It is dangerous to assume that these practices do not affect shark physiology or homeostasis, although this may be manifested on a species or case-specific basis. For example, certain operators place sharks into 'tonic immobility' (a trance-like state) to impress guests, however this practice has actually been shown to cause significant physiological and biochemical disruption and increase stress in sharks (Davie et al., 1993; Brooks et al., 2011). Despite the wide range of operator interactions with sharks, there are very few data on their effects. As such, we recommend these interactions be avoided until those data become available. This is particularly important if sharks are aggregated for key life-history phases where handling could hinder the sharks from engaging in critical behaviors (i.e., mating). Furthermore, improper operator handling of the sharks (i.e., trapping them between cages and boats, Fig. 3) could lead to a false impression among the public that the sharks may be aggressive.

Dive boats can cause noise pollution and physical obstruction that could interfere with shark behaviors such as feeding or hunting. For example, in the waters surrounding Seal Island in False Bay, South Africa, white sharks appear to use a search base or anchor point from which to stage attacks on seals (Martin et al., 2009). For that reason, dive boats tend to anchor at this location to attract sharks for viewing (Laroche et al., 2007). It is possible that the noise or obstruction caused by the boat and/or cage could interfere with sharks staging successful predations on seals, or create a shelter for seals as they are being hunted by sharks (AJG and NH, direct observation). At this same spot, seal decoys are often towed within the hunting spots to elicit strikes for tourists and film crews. Although the exact energetic values needed to launch a strike on a decoy remain unknown, this scenario could lead to reduced predation on seals and perhaps even aversion if sharks start to associate a seal shape with lack of a food reward. Moreover, it is possible sharks expend a portion of their daily energy budget on chasing seal decoys and thereafter cannot engage in other energy-expensive tasks. Thus, if shark diving tourism continues to be discussed as a non-consumptive activity, it is critical that potential sublethal and/or chronic impacts are enumerated, quantified, and reduced. However, the current scientific literature on animal welfare in shark tourism is limited, and the majority of those studies which have been conducted are often redundant and difficult to differentiate (see Table 1 for examples). Future studies should strive to collect data and test hypotheses that may help generate codes of compliance that will help improve animal welfare (i.e., Pierce et al., 2010).

6. Human dimensions

6.1. Socio-economics

Shark diving tourism has been responsible for a shift in the socio-economic importance of sharks from a fisheries product to a more valuable reusable resource in many tourist destinations around the world. Shark diving generates direct revenues for local operators, but the demand of participants for services beyond the immediate industry also stimulates the economic development of a range of local businesses (e.g., hotels and restaurants; Dicken and Hosking, 2009; Clua et al., 2011; Bradford and Robbins,

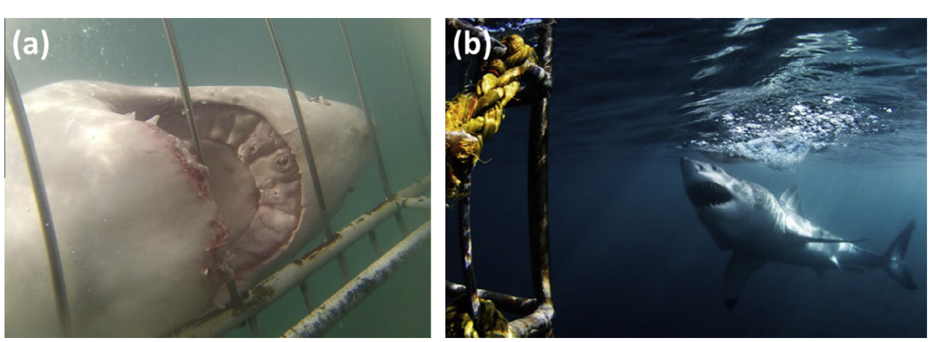

Fig. 3. Example of the variability in commitment to animal welfare among shark diving tourism operations, with a specific focus on great white shark cage diving/viewing in South Africa. (a) White shark is dragged into the cage and shows signs of previous physical trauma and tooth damage. (b) Seal decoy (pictured above the shark) is being dragged away from the cage (pictured left) in an effort to allow the shark time to steer away and prevent collision with cage. Both photos document two different operators who remain anonymous.

2013). Together, the commercial activities associated with this industry generate substantial tax revenues, increasing the capability of local and national governments to further provide services and infrastructure to the general community (Vianna et al., 2011, 2012).

Socio-economic studies of shark diving have been conducted at many scales. A few have attempted to estimate the average economic value of individual animals resident at shark diving sites with the aim of contrasting the non-consumptive versus consumptive values (Clua et al., 2011; Vianna et al., 2012). Since the non-consumptive values of sharks are typically orders of magnitude higher (Vianna et al., 2012), such figures are commonly used by advocacy groups as a reason to enact shark protective measures from fishing. However, valuations studies at the scale of individual animals have been a source of recent debate in the scientific community (Catlin et al., 2013; Vianna et al., 2013), with estimates on larger scales (whole industry or population level) regarded as more suitable in situations where basic information about the residence and identity of individuals and populations may not be available (Vianna et al., 2013). However, there is a lack of quantification of the net benefits from shark diving that are incorporated to the community, particularly those communities that are simultaneously exploiting sharks for food products.

Valuation studies have been important to show the contribution of the shark diving industry to economies on regional and nationwide scales, and they typically quantify the direct and indirect expenditures of participants engaged in shark diving as the non-consumptive use value of the industry (e.g., Dicken and Hosking, 2009; Clua et al., 2011). Direct expenditures have been quantified as the expenditures of participants purchasing a shark-diving package from the tourist operator (usually obtained through structured interviews or questionnaires), with indirect expenditures representing the other costs that might be related to the presence of participants such as accommodation, living costs, souvenirs and even airfare (De la Cruz Modino et al., 2010; Clua et al., 2011). For example, in 2007, a specialized shark diving industry focusing on tiger sharks on the east coast of South Africa was estimated to generate annual revenues of approximately US$1.8 million to the coastal communities in the area (Dicken and Hosking, 2009), while in Moorea (French Polynesia) shark diving with lemon sharks (*Negaprion acutidens*) was estimated to generate over US$5.4 million annually (Clua et al., 2011). Also, in Palau, the shark diving industry generated approximately US$19 million in 2010, with benefits to the local community of US$1.2 million in salaries (Vianna et al., 2012). This industry accounted for 8% of the Gross Domestic Product of the country and represented the third highest contributor to the gross tax revenue. Similarly in Fiji, a well-established shark diving industry was estimated to generate approximately US$42 million annually at a nationwide scale. Of this amount, approximately US$4 million was directly assimilated by the local communities (Vianna et al., 2011).

Recently, Cisneros-Montemayor et al. (2013) employed a meta-analytical approach to estimate the global value of shark diving tourism. These authors estimated that shark diving generated annual revenues in the order of US$314 million, directly supporting around 10,000 jobs. Many of the results of this paper were rebutted by Brunnschweiler and Ward-Paige (2014) and other colleagues in the field, who argue that these figures underestimate the economic value of shark diving and fail to account for empirical data available in the literature. Despite the debate over precision of estimates, the greater literature clearly shows that the socio-economic benefits from the shark diving industry are both large and widespread, however, these revenues are much lower than those generated by other wildlife tourism industries which appeal to wider audience of users such as whale-watching (c.f. US$ 2 billion/year; O'Connor et al., 2009).

The economic figures from empirical valuations and global demographic analyses have provided early insight into the scale of shark diving, however, inconsistency in methods among studies and time lags among estimates may limit the ability to compare between studies. Instead, a standardization of protocols for data collection and analysis may permit transparency and comparability of any generated estimates with competing industries (e.g. fishing industry), and will be important to generate longitudinal data that might be used to monitor trends in the shark diving industry and the socio-economic importance of shark tourism for the livelihood of local communities over time.

People's willingness to pay to conserve wildlife has been demonstrated to be linked to variables including the size of a species population, the relative costs of conservation, the type of species, whether it has both "use" and "non-consumptive" value, and whether the species constitutes "charismatic megafauna" (Richardson and Loomis, 2009). These values will vary widely based on species' individual characteristics, and thus economic values ascribed to charismatic shark species or commercially important shark species cannot be extrapolated to all elasmobranchs.

In addition to the direct and indirect expenditures of shark tourists, evidence suggests that tourists are more willing to pay to support the conservation of species they have encountered (Tisdell and Wilson, 2001). Moreover, the economic analyses reviewed here do not account for the "existence" value of sharks to environmentally minded individuals, which can constitute a significant portion of a wildlife species' estimated total value (Bandara and Tisdell, 2003). A greater emphasis should be placed on human dimensions research in the future, specifically that which uses social science approaches to understand local cultures and communities associated with shark diving.

6.2. Conservation and research

Wildlife tourism, including shark diving tourism, can be a powerful argument for the conservation of biodiversity (Walpole and Leader-Williams, 2002). While we believe that shark diving tourism has potential conservation benefits, it is worth considering the potential positive and negative effects on conservation that may result from these practices.

There is a growing trend in creating Marine Protected Areas around shark diving locations (i.e., Guadalupe Island, Fiji Shark Reef) and even very large shark-specific sanctuaries in countries where shark diving tourism contributes significantly to the nation's GDP (i.e., Palau, Bahamas). In some cases, the year-round presence of operators and eco-tourists at these sites essentially creates a *defacto* protected area, serving as monitors, alarms and deterrents for poachers or fishermen engaging in illegal activities. However, as new shark diving sites are discovered and advertised, they can become a target for the exploitation of sharks, as seen in the local extirpation of an annual stock of bull sharks at a dive site in Mexico or the illegal poaching of Caribbean Reef sharks at a popular feeding site in the Bahamas (Authors, direct observation). Moreover, while there are indeed fishers switching from shark harvesting to tourism, these changes can be challenging due to language barriers, education, start-up capital, and the expectations of Western tourists. In some cases, foreign investment can be a crucial and welcome component of development strategies based on wildlife tourism (e.g., Wunder, 2000), while in others tourism income may be largely directed away from local people, whose participation is often limited to menial, poorly paid "service" jobs (e.g., Mbaiwa, 2003). In some cases, growing reliance on tourism dollars can lead to increasing local hostility toward tourists themselves, as purchases create local inflation or tourists fail to observe local cultural norms (Walpole and Goodwin, 2001).

Important debates exist about using economic valuation of specific species or ecosystems as a tool for conservation, particularly given the role of morality and ethics in making such decisions. Many of the most significant conservation victories of previous decades were argued on moral and ethical rather than economic grounds (for example, commercial whaling bans, or the CITES bans on international trade in ivory) (McCauley, 2006). Thus, while valuation may be a useful way of communicating about the economic importance of specific species in specific settings, conservation arguments that rely solely on economic rationality and market forces to conserve wildlife are significantly weakened.

Operators often maintain detailed daily logs of shark abundance and community changes, and can identify sharks to the individual level, monitor their health over time, and detect anomalies in local faunal patterns (e.g., Meyer et al., 2009; Towner et al., 2013; Fallows et al., 2013). As such, operators can be a useful source and partner for scientific investigations and many of the papers cited throughout benefitted from operator support (although proper training may be required).

While the potential benefits of responsible tourism to scientists and natural resource managers are clear, there is skepticism and debate about whether wildlife tourism ultimately leads to positive conservation outcomes. While operators genuinely believe that the personal experiences tourists have with sharks result in attitudinal change (CCM, unpublished data), the findings of tourism researchers have been more equivocal. Pre-existing pro-environmental attitudes have been shown to be an important predictor of learning in a wildlife tourism setting, suggesting that these experiences are likely to be most effective at communicating with those who already possess environmental awareness and a conservation ethos, and are more likely to lead to learning than to long term attitudinal or behavioral change (Ballantyne et al., 2011). In addition to reinforcing existing beliefs, ecotourism can help to create new, positive attitudes among the previously ambivalent (i.e., "I didn't really care about sharks before...") but shows a limited ability to change pre-existing attitudes or result in lasting behavioral changes (Smith et al., 2011). Finally, even in those cases in which tourists have profound affective experiences with wildlife, they may find it difficult to verbally communicate their experiences, limiting the potential for attitudinal change to spread through social networks (Milstein, 2008). Qualitative and quantitative social science methods could be useful for future work seeking to address this issue. While there is undoubtedly potential for wildlife tourism to contribute to conservation, that contribution is not necessarily intrinsic to the tourism experience itself, and will be dependent on the quality of operator and educational opportunities provided (Curtin, 2010). Of course, this also does not account for the possibility of shark tourism having a negative impact on public perceptions of sharks in case of a shark-related injury to a tourist.

6.3. Community-based management

There are several instances where shark diving tourism has led local villages to use the community-based management of sites to establish local Marine Protected Areas, monitored and enforced by the community and recognized by the government (Brunnschweiler, 2010). In Fiji, conservation groups and dive businesses have established long-term partnerships with the local community, returning part of the revenues generated by shark diving to the villages in exchange for the fishing rights at shark diving sites (Brunnschweiler, 2010; Vianna et al., 2011). Similarly, the community-based management of a local whale shark (*Rhincodon typus*) diving industry in Donsol, Philippines, has ensured that the revenues generated by shark diving were largely translated into socio-economic benefits for the local villages (Pine et al., 2007). With the support of local government and a Non-Governmental Organization (NGO), a community-based management system commissioned local fishers to operate shark-snorkeling trips for tourists using their fishing boats (Quiros, 2005; Pine et al., 2007).

In cases where community-based management has not occurred, the success of shark tourism as a mechanism for development and community employment is more mixed; in some locales fishers may not have the resources or infrastructure to exploit a growing demand for shark dive tourism, and communities may feel deprived of access to valuable shark fisheries without compensation (Rodríguez-Dowdell et al., 2007). In these cases, there is much greater potential for poaching and resistance to dive tourism among local populations. Although this system benefits from the involvement of locals throughout the process of decision making, the direct participation of government authorities and NGOs promotes interaction between the stakeholders, while providing specialized training and support for management of the industry (Quiros, 2005). However, the economic benefits may not necessarily parlay into pro-conservation attitudes, particularly if the benefits of economization are not communicated sufficiently (Burns, 2004).

6.4. Citizen science initiatives

Shark diving tourism presents itself as a potential instrument and platform for the implementation of citizen science initiatives, and recreational shark divers have assisted in the collection of scientific data in numerous ways. For example, by using an underwater visual census carried out by trained volunteers, large-scale declines in shark populations throughout the Caribbean were revealed, mainly resultant from overfishing (Ward-Paige et al., 2010). Additionally, photos collected by recreational shark divers were used to describe the population structure, site use and movements patterns of grey nurse sharks (*Carcharias taurus*) and whale sharks off Australia (Barker and Williamson, 2010; Davies et al., 2012). In Fiji, well-structured programs have also been employed to monitor the status and demography of shark populations over time (Brunnschweiler and Baensch, 2011). The validity of the data collected in these programs relies on the skills of the participants in detecting, identifying and estimating the number of sharks present. For this reason, the use of untrained observers may represent an important source of bias in count data collected by shark-diving tourism (Meyer et al., 2009). While citizen science programs designed to collect data to support research are indeed a valuable tool, the efficiency of such programs for science can only be achieved by having clear objectives and hypotheses that can be realistically tested and published (Brunnschweiler and Baensch, 2011; Ward-Paige and Lotze, 2011; Ward-Paige et al., 2011). Finally, it is fundamental to establish protocols to ensure standardization and data quality that may allow the establishment of citizen-scientist networks for the collection of data for broad-scale monitoring projects (Huveneers et al., 2009; Vianna et al., 2014).

6.5. Bites on humans

Perhaps the biggest and most controversial concern over shark diving is the potential to cause safety issues for recreational water users. Despite millions of dedicated shark dives occurring annually around the globe, there are very few instances of people being harmed by sharks during dedicated shark dives. According to the International Shark Attack File (ISAF), there were 38 and 34 'unprovoked' shark bites on humans divers (those entering the water and submerging) worldwide between 1990–1999 and 2000–2012, respectively (averaging between 12% and 40% fatal, ISAF). These descriptive statistics should be treated with caution, however, as it includes interactions with spear-fishers but does not specify whether these interactions occurred during shark diving tourism activities. A controversial aspect of shark diving is the concern that diver-shark interactions and/or the use of bait or food-rewards will habituate sharks to people or cause sharks to associate people with food, therefore, creating a significant safety concern for any water users, such as bathers. While sharks are certainly capable of learning (see Section 1 on learning), we are not aware of any published studies that have examined such a scenario and therefore, this is certainly an area requiring further research. However, research on a variety of other species has shown that some increased risk of aggression toward humans is possible in provisioned animals. In one study, researchers showed a strong correlation between the amount of time provisioned dolphins were made to wait before being fed and the probability of potentially dangerous interactions between dolphins and humans at the feeding site (Smith et al., 2008). Moreover, provisioned animals are more likely to engage in "begging" behavior, which has been reported for species including deer (Hockett, 2000), dolphins (Orams, 1997), iguanas (de Groot, 1983), macaques (Knight, 2010) and bear (Tate and Pelton, 1983), with sometimes disastrous consequences for wildlife or humans. There is no doubt that shark diving, like other forms of wildlife viewing involving mobile predators, is potentially dangerous. Clearly, the potential relationships between shark diving and human safety is a much needed area of important research. This is not only important in terms of human safety, but a shark bite on a human can quickly undermine any conservation progress that has shown the benefits of live sharks to human society (versus dead) or dispelling their negative image as 'man eaters', which often caused people to hunt them or receive little conservation attention. While the direct impacts of feeding activities are often not acutely obvious or clear (see previous sections on learning and behavior), extreme caution should be taken when interacting with wild animals and operators should certainly not operate in areas close to other water users.

7. Practice

There are currently no universal best practices that are applied to shark diving, which, although likely difficult to standardize to due species-specific differences, may be warranted in light of variation in operator behavior and the inherent risks associated with diving and interacting with large and potentially dangerous predators. Inadequately regulated marine tourism has been demonstrated to negatively impact many types of marine wildlife including cetaceans, sea birds, seals, manatees and stingrays (e.g., Newsome et al., 2004; Semeniuk et al., 2009; Sorice et al., 2006; Steckenreuter et al., 2011; Velando and Munilla, 2011; Andersen et al., 2012). Authors have contended that a lack of certainty that harm is occurring can potentially be misleading, as negative impacts may not be immediate, obvious or easy to detect (Sorice et al., 2003). Good practices sustain the exploited resource while providing access to users – a result of a healthy working relationship between conservationists, policy makers, and the industry. However, regulating behavior in human–wildlife scenarios can be difficult. The United States Fish and Wildlife Service has found extreme difficulty in regulating the behavior of tourists swimming with manatees in shallow inshore waters where most encounters and infractions take place at the surface (Sorice et al., 2006). Indeed, even in places where shark provisioning has been banned, enforcement of these bans has proven extremely difficult (CCM unpublished data). Under these conditions, it is realistic to assume that managing agencies will find shark tourism that takes place in remote locations and at depth far more complex and challenging to regulate effectively.

Table 4
Hypothetical scorecard that could be used to quantitatively assess the quality, performance, and safety of shark diving tourism operations.

	Poor (1)	Fair (2)	Good (3)	Excellent (4)	Score
Educational information	Operators provide little, if any, information on the diving and animals; no guidelines provided on animal interactions	Brief overview of diving conditions and animals; no guidelines provided on animal interactions	Basic briefing of diving conditions, diver safety, animals; some guidelines provided on animal interactions	Very thorough briefings on diving conditions, diver safety with an emphasis on animal behavior; detailed guidelines on animal interactions provided	
In-water safety	Operation is a free-for-all with no organization; operators make no effort to lead/communicate underwater	Operation exhibits loose organization between divers and operators; operators remain relatively distant from divers	Operation exhibits good organization and communication between divers and operators; operators stay relatively close to divers	Operation demonstrates effective strategy with strong organization and frequent communication with divers; entry/exit protocol enforced	
Animal treatment	Operators frequently handle and manipulate animals and permit divers to handle and touch	Operators sometimes handle and manipulate animals; limiting touching by divers is not enforced	Operators rarely handle or manipulate animals; touching by divers is prohibited and enforced	Operators never handle or manipulate animals; touching by divers is strictly prohibited and enforced	
Environmental sustainability	Operators make no efforts to use local or natural (or low trophic-level) bait; gear used for animal interactions is high-impact; vessel is not fuel-efficient; no involvement to seed local community	Operators rarely use local or natural bait; gear used has moderate-impact; vessel is moderately fuel-efficient; minimal involvement with local community	Operators use local and natural bait; gear used has moderate to low impact; vessel is fuel-efficient; local communitiy is involved somehow in the operation	Operators always use local bait that is natural prey of animals and ideally source the bait from fisher or restaurant surplus (or use no bait); gear is specifically designed to be low-impact; vessel is certified fuel-efficient and low emission; local community is involved in the operation (jobs, etc)	
Conservation ethic	Operation is not designed to benefit the conservation of resources, animals, or local communities and waters	Operation demonstrates basic aspects of conservation-mentality with regards to resources, animals, communities, and waters	Operation demonstrates a clear conservation-based approach with regards to resources, animals, communities, and waters	Operation highly demonstrates a conservation-based approach with regards to resources, animals, communities, and waters	
				Total score	(/ 20)

One common approach to regulation of wildlife tourism has been voluntary codes of conduct. In many cases, these codes are created and overseen by the tourism industry itself; however they have shown mixed success as regards compliance. Quiros (2007) found that compliance to "code of conduct" regulations for interactions with whale sharks in the Philippines in 2004 and 2005 was irregular, with only 44% of divers maintaining the required minimum distance from the sharks and 18% disobeying the prohibition on touching sharks. Similar findings with dolphins suggest that operator behavior was compliant to a voluntary code of conduct on only 40% of tourism trips—even when crew members were aware an observer/researcher was on board (Scarpaci et al., 2003). Despite these limitations, given the present scale of marine wildlife tourism and available enforcement resources, a code of conduct is likely to be the most realistic approach to regulating shark tourism. Evaluating or developing shark diving best-practice is beyond the scope of this paper, but they should be science-based, explicit and relatively easy to obey and enforce (Pierce et al., 2010). However, we propose employing a basic rating system (i.e., the 'star' system seen in hotels and restaurants) to assist tourists in making decisions for choosing responsible dive operators. For example, operators could be quantitatively scored from 1 (worst) to 4 (best) in the following categories: (a) educational information provided to divers; (b) in-water diver safety; (c) animal welfare; (d) ecological sustainability; and (e) conservation ethic (Table 4). Furthermore, tourist-generated photo and video placed on social media and other websites may also help monitor operator practices; these could be used in conjunction with an operator-by-operator rating tool similar to the one proposed above.

8. Conclusions and future directions

Research into various aspects of shark diving tourism appears to be trending, especially in recent years as researchers have switched from solely describing the socio-economics of a regional industry toward designing multi-year investigations which seek to understand the true impacts on shark behavior and its potential indirect effects on both natural systems and humans. While a strong foundation of research exists to begin assessing and making conclusions on the ecological and behavioral impacts of shark diving practices as well as its potential economic importance, many questions remain (Table 2). The costs, benefits, and risks associated with shark diving are likely specific to the species, location, and perhaps even individual-level. Thus, as scientists, we need to be thoughtful about these challenges when we frame our research questions, as well as the limitations when we interpret our results. This is underscored by some degree of skepticism which clearly exists within the scientific community, as evidenced by the published comments/rebuttals in reference to previously published work. As a collective group of researchers, we should be open to collaborations and communications such that we avoid potential pitfalls (redundancy, over-saturation of topics, lack of controls, disagreements) that may stunt the evolution of this area of study. We also need to think carefully about how we influence or attempt to influence the manner in which our results are disseminated to the popular media or on social media platforms. The latter is likely to play an important role in how practices in the industry are perceived by the general public, and could be a valuable source of data for future investigations.

Identifying possible changes in animal ecology and biology as a result of human–wildlife interactions is the first step in assessing impacts of shark diving tourism activities. However, given that a certain level of impact from tourism or ecotourism may always be expected, it is fundamental for future research to focus on the extent and relevance of this interference on the shark populations, and how provisioning may influence the health of the animals and risk to humans. It is also crucial to define and frame what type of "impact" is under investigation. Furthermore, research projects should make an effort to have appropriate biologically relevant controls (*sensu* Hammerschlag et al., 2012).

Shark diving tourism is a controversial topic. Research in this field can benefit from collaborations between researchers and industry representatives, although projects should mitigate the potential validity threats imposed by operators. While they may not be ideal or universally valid, codes of conduct, rating systems and safety guidelines should be explored. Despite the need to increase our understanding of the potential effects of shark diving on animal welfare and human safety, we emphasize a precautionary approach be used by operators and tourists and therefore, certain practices should be avoided, namely: operating in close proximity to other human-use areas, touching, manipulating and harassment of animals, hand-feeding, direct interference with critical shark behaviors, poor normal diving practices, uncontrolled swimming, as well as uneducated and unregulated mass diving in the presence of provisioning (Orams, 2002). There appear to be no net benefits of these actions (except perhaps 'happier' clients) over more precautionary practices, and although they may actually be benign, they inherently pose added safety risk to users and sharks. We thus suggest that a universal code of conduct be created to ensure both human and shark safety. Because shark diving tourism has the potential to provide significant long term conservation and economic benefits for a small handful of species and communities which can exploit them, decisions about regulation or banning feeding should be based on scientific research; however, a precautionary approach should be taken to ensure human safety, reduce environmental impacts, promote economic benefits and foster shark conservation.

Acknowledgements

We thank the staff of the Marine Conservation Research Laboratory and the Abess Center for Ecosystem Science and Policy, specifically D. Shiffman. Additionally, we are grateful for the meaningful discussions had with various colleagues and experiences with shark diving operators who have provided us first-hand insights from which this paper benefitted. We thank the two anonymous reviewers whose comments strengthened this manuscript.

References

Allgeier, J.A., Yeager, L.A., Layman, C.A., 2013. Consumers regulate nutrient limitation regimes and primary production in seagrass ecosystems. Ecology 94, 521–529.

Altmann, J., Muruthi, P., 1988. Differences in daily life between semiprovisioned and wild feeding baboons. Am. J. Primatol. 15, 213–221.

Andersen, S.M., Teilmann, J., Dietz, R., Schmidt, N.M., Miller, L.A., 2012. Behavioural responses of harbour seals to human-induced disturbances. Aquat. Conserv.: Mar. Freshwater Ecosyst. 22, 113–121. http://dx.doi.org/10.1002/aqc.1244.

Anderson, D.J., Kobryn, H.T., Norman, B.M., Bejder, L., Tyne, J.A., Loneragan, N.R. 2014. Spatial and temporal patterns of nature-based tourism interactions with whale sharks (*Rhincodon typus*) at Ningaloo Reef, Western Australia. Estuar., Coast. Shelf Sci. 148, 109–119, http://dx.doi.org/10.1016/j.ecss.2014.05.023

Apps, K., Lloyd, D., Dimmock, K., 2014. Scuba diving with the grey nurse shark (Carcharias taurus): an application of the theory of planned behaviour to identify divers beliefs. Aquat. Conserv.: Mar. Freshwater Ecosyst. (in press). http://dx.doi.org/10.1002/aqc.2430.

Aronson, L.R., Aronson, F.R., Clark, E., 1967. Instrumental conditioning and light–dark discrimination in young nurse sharks. Bull. Mar. Sci. 17, 249–256.

Ballantyne, R., Packer, J., Falk, J., 2011. Visitors' learning for environmental sustainability: testing short- and long-term impacts of wildlife tourism experiences using structural equation modelling. Tourism Manage. 32, 1243–1252. http://dx.doi.org/10.1016/j.tourman.2010.11.003.

Bandara, R., Tisdell, C.A., 2003. Use and non-use values of wild Asian elephants: a total economic valuation approach. Economics, Ecology and Environment Working Papers. School of Economics, University of Queensland.

Barker, S.M., Williamson, J.E., 2010. Collaborative photo-identification and monitoring of grey nurse sharks (*Carcharias taurus*) at key aggregation sites along the eastern coast of Australia. Mar. Freshwater Res. 61, 971–979.

Barker, S.M., Peddemors, V.M., Williamson, J.E., 2011a. A video and photographic study of aggregation, swimming and respiratory behaviour changes in the Grey Nurse Shark (Carcharias taurus) in response to the presence of SCUBA divers. Mar. Freshwater Behav. Physiol. 44, 75–92.

Barker, S.M., Peddemors, V.M., Williamson, J.E., 2011b. Recreational SCUBA diver interactions with the critically endangered grey nurse shark *Carcharias taurus*. Pac. Conserv. Biol. 16, 261–269.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., et al., 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conserv. Biol.: J. Soc. Conserv. Biol. 20, 1791–1798. http://dx.doi.org/10.1111/j.1523-1739.2006.00540.x.

Bejder, L., Samuels, A., Whitehead, H., Finn, H., Allen, S., 2009. Impact assessment research: use and misuse of habituation, sensitisation and tolerance to describe wildlife responses to anthropogenic stimuli. Mar. Ecol. Prog. Ser. 395, 177–185.

Bradford, R., Robbins, R., 2013. A rapid assessment technique to assist management of the white shark (*Carcharodon carcharias*) cage dive industry, South Australia. Open Fish Sci. J. 6, 13–18.

Brooks, E.J., Sloman, K.A., Liss, S., Hassan-Hassanein, L., Danylchuk, A.J., Cooke, S.J., Mandelman, J.W., Skomal, G.S., Sims, D.W., Suski, C.D., 2011. The stress physiology of extended duration tonic immobility in the juvenile lemon shark, *Negaprion brevirostris* (Poey 1868). J. Exp. Mar. Biol. Ecol. 409, 351–360.

Bruce, B.D., Bradford, R.W., 2013. The effects of shark cage-diving operations on the behaviour and movements of white sharks, *Carcharodon carcharias*, at the Neptune Islands, South Australia. Mar. Biol. 160, 889–907.

Brunnschweiler, J.M., 2010. The shark reef marine reserve: a marine tourism project in Fiji involving local communities. J. Sustain. Tourism 18, 29–42.

Brunnschweiler, J.M., McKenzie, J., 2010. Baiting sharks for marine tourism: comment on Clua et al. (2010). Mar. Ecol. Prog. Ser. 420, 283–284.

Brunnschweiler, J.M., Baensch, H., 2011. Seasonal and long-term changes in relative abundance of bull sharks from a tourist shark feeding site in Fiji. PloS One 6, e16597.

Brunnschweiler, J.M., Barnett, A., 2013. Opportunistic visitors: long-term behavioural response of bull sharks to food provisioning in Fiji. PloS One 8, e58522.

Brunnschweiler, J.M., Ward-Paige, C.A., 2014. Shark fishing and tourism. Oryx. http://dx.doi.org/10.1017/S0030605313001312.

Burns, G.L., 2004. The host community and wildlife tourism. In: Higginbottom, K. (Ed.), Wildlife Tourism: Impacts, Management and Planning. Common Ground Publishing, Altona, Victoria, pp. 125–144.

Cagua, E.F., Collins, N., Hancock, J. Rees, R. 2014. Whale shark economics: a valuation of wildlife tourism in South Ari Atoll, Maldives. PeerJ 2, e515, http://dx.doi.org/10.7717/peerj.515

Campbell-Smith, G., Campbell-Smith, M., Singleton, I., Linkie, M., 2011. Raiders of the lost bark: orangutan foraging strategies in a degraded landscape. PloS One 6, e20962.

Caro, T., 1994. Cheetahs of the Serengeti Plains. The University of Chicago Press, Chicago, IL.

Catlin, J., Jones, R., 2010. Whale shark tourism at Ningaloo Marine Park: a longitudinal study of wildlife tourism. Tourism Manage. 31, 386–394.

Catlin, J., Jones, T., Norman, B., Wood, D., 2010a. Consolidation in a wildlife tourism industry: the changing impact of whale shark tourist expenditure in the Ningaloo coast region. Int. J. Tourism Res. 12, 134–148.

Catlin, J., Jones, R., Jones, T., Norman, B., Wood, D., 2010b. Discovering wildlife tourism: a whale shark tourism case study. Curr. Issues Tourism 13, 351–361.

Catlin, J., Jones, T., Jones, R., 2012. Balancing commercial and environmental needs: licensing as a means of managing whale shark tourism on Ningaloo reef. J. Sustain. Tourism 20, 163–178.

Catlin, J., Hughes, M., Jones, T., Jones, R., Campbell, R., 2013. Valuing individual animals through tourism: science or speculation? Biol. Conserv. 157, 93–98.

Cisneros-Montemayor, A.M., Barnes, M., Al-Abdulrazzak, D., Navarro-Holm, E., Sumaila, U.R., 2013. Global economic value of shark ecotourism: implications for conservation. Oryx 47, 381–388.

Clark, E., 1963. The maintenance of sharks in captivity, with a report on their instrumental conditioning. In: Gilbert, P.W. (Ed.), Sharks and Survival. DC Heath, Boston, pp. 115–150.

Clarke, C., Lea, J.S.E., Ormond, R.F.G., 2011. Reef-use and residency patterns of a baited population of silky sharks, *Carcharhinus falciformis*, in the Red Sea. Mar. Freshwater Res. 62, 668–675.

Clarke, C.R., Lea, J.S.E., Ormond, R.F.G., 2013. Changing relative abundance and behaviour of silky and grey reef sharks baited over 12 years on a Red Sea reef. Mar. Freshwater Res. 64, 909–919.

Clua, E., Buray, N., Legendre, P., Mourier, J., Planes, S., 2010. Behavioural response of sicklefin lemon sharks Negaprion acutidens to underwater feeding for ecotourism purposes. Mar. Ecol. Prog. Ser. 414, 257–266.

Clua, E., Buray, N., Legendre, P., Mourier, J., Planes, S., 2011. Business partner or simple catch? The economic value of the sicklefin lemon shark in French Polynesia. Mar. Freshwater Res. 62, 764–770.

Creel, S., Fox, J.E., Hardy, A., Sands, J., Garrott, B., Peterson, R.O., 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. Conserv. Biol. 16, 809–814.

Cubero-Pardo, P., Herrón, P., González-Pérez, F., 2011. Shark reactions to scuba divers in two marine protected areas of the Eastern Tropical Pacific. Aquat. Conserv.: Mar. Freshwater Ecosyst. 21, 239–246.

Curtin, S., 2010. Managing the wildlife tourism experience: the importance of tour leaders. Int. J. Tourism Res. 12 (3), 219–236.

Davie, P.S., Franklin, C.E., Grigg, G.C., 1993. Blood pressure and heart rate during tonic immobility in the black tipped reef shark, Carcharhinus melanoptera. Fish Physiol. Biochem. 12 (2), 95–100.

Davies, M., 1990. Wildlife as a tourism attraction. Environments 20, 74–77.

Davies, T.K., Stevens, G., Meekan, M.G., Struve, J., Rowcliffe, J.M., 2012. Can citizen science monitor whale-shark aggregations? Investigating bias in mark–recapture modelling using identification photographs sourced from the public. Wildlife Res. 39, 696–704.

Davis, D., Banks, S., Birtles, A., Valentine, P., Cuthill, M., 1997. Whale sharks in Ningaloo Marine Park: managing tourism in an Australian marine protected area. Tourism Manage. 18, 259–271.

Davis, D., 1998. Whale shark tourism in Ningaloo Marine Park, Australia. Anthrozoos: A Multidiscipl. J. Interact. People Anim. 11, 5–11.

de Groot, R.S., 1983. Tourism and conservation in the Galapagos. Biol. Conserv. 26, 291–300.

De la Cruz Modino, R., Esteban, A., Crilly, R., Pascual-Fernandez, J., 2010. Bucear con tiburones y rayas en España. Análisis de su potencial en España y de los beneficios económicos de la actividad en las Islas Canarias. Instituto Universitario de Ciencias Politicas y Sociales de la Universidad de La Laguna y nef, pp. 8–16.

Dicken, M.L., Hosking, S.G., 2009. Socio-economic aspects of the tiger shark diving industry within the Aliwal Shoal Marine Protected Area, South Africa. Afr. J. Mar. Sci. 31, 227–232.

Dicken, M.L., 2014. Socio-economic aspects of the Sodwana Bay SCUBA diving industry, with a specific focus on sharks. Afr. J. Mar. Sci. 36, 39–47.

Dobson, J., 2006. Sharks, wildlife tourism, and state regulation. Tourism Mar. Environ. 3, 15–23.

Domeier, M.L., Nasby-Lucas, N., 2013. Two-year migration of adult female white sharks (*Carcharodon carcharias*) reveals widely separated nursery areas and conservation concerns. Anim. Biotelemetry 1, 1–10.

Duffus, D.A., Dearden, P., 1990. Non-consumptive wildlife-oriented recreation: a conceptual framework. Biol. Conserv. 53, 213–231.

Du Preez, M., Dicken, M., Hosking, S.G., 2012. The value of Tiger Shark diving within the Aliwal Shoal marine protected area: a travel cost analysis. South Afr. J. Econ. 80, 387–399.

Estes, J.A., Tinker, M.T., Williams, T.M., Doak, D.F., 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. Science 282, 473–476.

Fallows, C., Gallagher, A.J., Hammerschlag, N., 2013. White sharks (Carcharodon carcharias) scavenging on whales and its potential role in further shaping the ecology of an apex predator. PLoS One 8, e60797. http://dx.doi.org/10.1371/journal.pone.0060797.

Ferretti, F., Worm, B., Britten, G.L., Heithaus, M.R., Lotze, H.K., 2010. Patterns and ecosystem consequences of shark declines in the ocean. Ecol. Lett. 13, 1055–1071.

Fitzpatrick, R., Abrantes, K.G., Seymour, J., Barnett, A., 2011. Variation in depth of whitetip reef sharks: does provisioning ecotourism change their behaviour? Coral Reefs 30, 569–577.

Gallagher, A.J., Hammerschlag, N., 2011. Global shark currency: the distribution and frequency, and socio-economics of shark ecotourism. Curr. Issues Tourism 14, 797–812.

Gallagher, A.J., Wagner, D.N., Irschick, D.J., Hammerschlag, N., 2014. Body condition predicts energy stores in apex predatory sharks. Conserv. Physiol.

Guttridge, T.L., Brown, C., 2013. Learning and memory in the Port Jackson shark, Heterodontus portusjacksoni. Anim. Cognit. 17, 415–425. http://dx.doi.org/10.1007/s10071-013-0673-4.

Guttridge, T.L., Myrberg, A.A., Porcher, I.F., Sims, D.W., Krause, J., 2009. The role of learning in shark behaviour. Fish Fisher. 10, 450–469.

Hammerschlag, N., Gallagher, A.J., Wester, J., Luo, J., Ault, J.S., 2012. Don't bite the hand that feeds: assessing ecological impacts of provisioning ecotourism on an apex marine predator. Funct. Ecol. 26, 567–576.

Hammerschlag-Peyer, C.M., Layman, C.A., 2010. Intrapopulation variation in habitat use by two abundant coastal fish species. Mar. Ecol. Prog. Ser. 415, 211–220.

Hayward, M.W., Hayward, G.J., 2009. The impact of tourists on lion *Panthera leo* behaviour, stress and energetics. Acta theriol. 54, 219–224.

Hockett, K.S., 2000. The effectiveness of two interpretations on reducing deer feeding behavior by park visitors. Unpublished Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Huveneers, C., Luo, K., Otway, N.M., Harcourt, R.G., 2009. Assessing the distribution and relative abundance of wobbegong sharks (Orectolobidae) in New South Wales, Australia, using recreational scuba-divers. Aquat. Living Resour. 22, 255–264.

Huveneers, C., Rogers, P.J., Beckman, C., Semmens, J., Bruce, B., Seuront, L., 2013. Effects of a cage-diving operation on the fine-scale movement of white sharks. Mar. Biol. http://dx.doi.org/10.1007/s00227-013-2277-6.

Johnson, R., Kock, A., 2006. White shark cage diving – cause for concern? In: Nel, D.C., Peshak, T. (Eds), Finding a Balance: White Shark Conservation and Recreational Safety in the Inshore Waters of Cape Town, South Africa.

Jones, T., Wood, D., Catlin, J., Norman, B., 2009. Expenditure and ecotourism: predictors of expenditure for whale shark tour participants. J. Ecotourism 8, 32–50.

Kamal, K., Boug, A., Brain, P.F., 1997. Effects of food provisioning on the behaviour of commensal Hamadryas baboons, Papio hamadryas, at Al Hada Mountain in western Saudi Arabia. Zool Middle East 14, 11–20.

Kawecki, T.J., 2010. Evolutionary ecology of learning: insights from fruit flies. Populat. Ecol. 52, 15–25.
Kimber, J.A., Sims, D.W., Bellamy, P.B., Gill, A.B., 2014. Elasmobranch cognitive ability: using electroreceptive foraging behaviour to demonstrate learning, habituation and memory in a benthic shark. Anim. Cognit. 17, 55–65.
Knight, J., 2009. Making wildlife viewable: habituation and attraction. Soc. Anim. 17, 167–184.
Knight, J., 2010. The ready-to-view wild monkey. Ann. Tourism Res. 37, 744–762.
Kruger, O., 2005. The role of ecotourism in conservation: panacea or Pandora's box? Biodivers. Conserv. 14, 579–600.
Laroche, R.K., Kock, A.A., Dill, L.M., Oosthuizen, W.H., 2007. Effects of provisioning ecotourism activity on the behaviour of white sharks *Carcharodon carcharias*. Mar. Ecol. Prog. Ser. 338, 199–209.
Larsson, P., Hamrin, S., Okla, L., 1990. Fat content as a factor inducing migratory behavior in the eel (*Anguilla anguilla* L.) to the Sargasso Sea. Naturwissenschaften 77, 488–490.
Lieberman, D.A., 1990. Learning: Behavior and Cognition. Wadsworth, Belmont, California, pp. 500.
Maljković, A., Côté, I.M., 2011. Effects of tourism-related provisioning on the trophic signatures and movement patterns of an apex predator, the Caribbean reef shark. Biol. Conserv. 144, 859–865.
Martin, R.A., Rossmo, D.K., Hammerschlag, N., 2009. Hunting patterns and geographic profiling of white shark predation. J. Zool. 279, 111–118.
Matich, P., Heithaus, M.R., Layman, C.A., 2011. Contrasting patterns of individual specialization and trophic coupling in two marine apex predators. J. Anim. Ecol. 80, 294–305.
Mau, R., 2008. Managing for conservation and recreation: the Ningaloo whale shark experience. J. Ecotourism 7, 213–225.
Mbaiwa, J.E., 2003. The socio-economic and environmental impacts of tourism development on the Okavango Delta, north-western Botswana. J. Arid Environ. 54, 447–467. http://dx.doi.org/10.1006/jare.2002.1101.
McCauley, D.J., 2006. Selling out on nature. Nature 443, 27–28.
McClung, M., Seddon, P., Massaro, M., Setiawan, A., 2004. Nature-based tourism impacts on yellow-eyed penguins *Megadyptes antipodes*: does unregulated visitor access affect fledging weight and juvenile survival? Biol. Conserv. 119, 279–285.
Meyer, C.G., Dale, J.J., Papastamatiou, Y.P., Whitney, N.M., Holland, K.N., 2009. Seasonal cycles and long-term trends in abundance and species composition of sharks associated with cage diving ecotourism activities in Hawaii. Environ. Conserv. 36, 104–111.
Milstein, T., 2008. When whales "Speak for Themselves": communication as a mediating force in wildlife tourism. Environ. Commun.: J. Nat. Culture 2, 173–192. http://dx.doi.org/10.1080/17524030802141745.
Newsome, D., Lewis, A., Moncrieff, D., 2004. Impacts and risks associated with developing, but unsupervised, stingray tourism at Hamelin Bay, Western Australia. Int. J. Tourism Res. 6, 305–323.
Müllner, A., Eduard Linsenmair, K., Wikelski, M., 2004. Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (Opisthocomus hoazin). Biol. Conserv. 118, 549–558. http://dx.doi.org/10.1016/j.biocon.2003.10.003.
O'Connor, S., Campbell, R., Cortez, H., Knowles, T., 2009. Whale Watching Worldwide: Tourism Numbers, Expenditures and Expanding Economic Benefits. International Fund for Animal Welfare, Yarmouth, MA.
Orams, M.B., 1997. Historical accounts of human–dolphin interaction and recent developments in wild dolphin based tourism in Australasia. Tourism Manage. 18, 317–326.
Orams, M.B., 2002. Feeding wildlife as a tourism attraction: issues and impacts. Tourism Manage. 23, 281–293.
Papastamatiou, Y.P., Cartamil, D.P., Lowe, C.G., Meyer, C.G., Wetherbee, B.M., Holland, K.N., 2011. Scales of orientation, directed walks and movement path structure in sharks. J. Anim. Ecol. 80, 864–874.
Papastamatiou, Y.P., Meyer, C.G., Carlvaho, F., Dale, J.J., Hutchinson, M.R., Holland, K.N., 2013. Telemetry and random walk models reveal complex patterns of partial migration in a large marine predator. Ecology 94, 2595–2606.
Pierce, S.J., Méndez-Jiménez, A., Collins, K., Rosero-Caicedo, M., 2010. Developing a code of conduct for whale shark interactions in Mozambique. Aquat. Conserv.: Mar. Freshwater Ecosyst. 20, 782–788.
Pine, R., Alava, M.N.R., Yaptinchay, A.A., 2007. Challenges and lessons learned in setting-up a community-based whale shark eco-tourism program: the case in Donsol, Philippines. In: The First International Whale Shark Conference: Promoting International Collaboration in Whale Shark Conservation, Science and Management. Conference Overview, Abstracts and Supplementary Proceedings. CSIRO Marine and Atmospheric Research, Wembley, Australia, pp. 36–44.
Piñeiro, A., Barja, I., Silván, G., Illera, J., 2012. Effects of tourist pressure and reproduction on physiological stress response in wildcats: management implications for species conservation. Wildlife Res. 39, 532–539.
Quiros, A., 2005. Whale shark" ecotourism" in the Philippines and Belize: evaluating conservation and community benefits. Trop. Resour.: Bull. Yale Trop. Resour. Inst. 24, 42–48.
Quiros, A.L., 2007. Tourist compliance to a Code of Conduct and the resulting effects on whale shark (*Rhincodon typus*) behavior in Donsol, Philippines. Fisher. Res. 84, 102–108.
Rescorla, R.A., 2008. Within-subject renewal in sign tracking. Q. J. Exp. Psychol. 61 (12), 1793–1802.
Richardson, L., Loomis, J., 2009. The total economic value of threatened, endangered and rare species: an updated meta-analysis. Ecol. Econ. 68, 1535–1548.
Rodríguez-Dowdell, N., Enríquez-Andrade, R., Cárdenas-Torres, N., 2007. Property rights-based management: whale shark ecotourism in Bahia de los Angeles, Mexico. Fisher. Res. 84, 119–127.
Rowat, D., Engelhardt, U., 2007. Seychelles: a case study of community involvement in the development of whale shark ecotourism and its socio-economic impact. Fisher. Res. 84, 109–113.
Scarpaci, C., Dayanthi, N., Corkeron, P.J., 2003. Compliance with regulations by "swim-with-dolphins" operations in Port Phillip Bay, Victoria, Australia. Environ. Manage. 31, 342–347. http://dx.doi.org/10.1007/s00267-002-2799-z.
Schluessel, V., 2014. Who would have thought that 'jaws' also has brains? Cognitive functions in elasmobranchs. Anim. Cognit. 10. http://dx.doi.org/10.1007/s10071-014-0762-.
Semeniuk, C.A.D., Bourgeon, S., Smith, S.L., Rothley, K.D., 2009. Hematological differences between stingrays at tourist and non-visited sites suggest physiological costs of wildlife tourism. Biol. Conserv. 142, 1818–1829. http://dx.doi.org/10.1016/j.biocon.2009.03.022.
Shiffman, D.S., 2014. Shark riders pose threat to conservation gains made with diving ecotourism. Scientific American. 3 March 2014. <http://www.scientificamerican.com/article/shark-riders-pose-threat-to-conservation-gains-made-with-diving-ecotourism-slide-show1/> (accessed 08.09.14).
Shiffman, D.S., 2014. No, harassing a shark for fun is not ethically equivalent to scientific research that helps conserve a species. Southern Fried Science. 26 March 2014. <http://www.southernfriedscience.com/?p=16842> (accessed 08.09.14).
Smith, H., Samuels, A., Bradley, S., 2008. Reducing risky interactions between tourists and free-ranging dolphins (Tursiops sp.) in an artificial feeding program at Monkey Mia, Western Australia. Tourism Manage. 29, 994–1001. http://dx.doi.org/10.1016/j.tourman.2008.01.001.
Smith, K., Scarr, M.J., Scarpaci, C., 2009. Does grey nurse shark (*Carcharias taurus*) diving tourism promote biocentric values within participants? J. Proc. Roy. Soc. New South Wales 142, 31–44.
Smith, K., Scarr, M., Scarpaci, C., 2010. Grey nurse shark (Carcharias taurus) diving tourism: tourist compliance and shark behaviour at Fish Rock, Australia. Environ. Manage. 46, 699–710.
Smith, L.D.G., Ham, S.H., Weiler, B.V., 2011. The impacts of profound wildlife experiences. Anthrozoos: Multidiscipl. J. Interact. People Anim. 24, 51–64. http://dx.doi.org/10.2752/175303711X12923300467366.
Smith, K.R., Scarpaci, C., Scarr, M.J., Otway, N.M., 2014. Scuba diving tourism with critically endangered grey nurse sharks (*Carcharias taurus*) off eastern Australia: tourist demographics, shark behaviour and diver compliance. Tourism Manage. 45, 211–225.
Sorice, M.G., Shafer, C.S., Scott, D., 2003. Managing endangered species within the use/preservation paradox: understanding and defining harassment of the West Indian manatee (*Trichechus manatus*). Coast. Manage. 31, 319–338.
Sorice, M.G., Shafer, C.S., Ditton, R.B., 2006. Managing endangered species within the use–preservation paradox: the Florida Manatee (*Trichechus manatus latirostris*) as a tourism attraction. Environ. Manage. 37, 69–83.
Speed, C.W., Meekan, M.G., Rowat, D., Pierce, S.J., Marshall, A.D., Bradshaw, C.J.A., 2008. Scarring patterns and relative mortality rates of Indian Ocean whale sharks. J. Fish Biol. 72, 1488–1503.
Steckenreuter, A., Harcourt, R., Möller, L., 2011. Distance does matter: close approaches by boats impede feeding and resting behaviour of Indo-Pacific bottlenose dolphins. Wildlife Res. 38, 455. http://dx.doi.org/10.1071/WR11048.
Tate, J., Pelton, M.R., 1983. Human-bear interactions in Great Smoky Mountains National Park. Int. Conf. Bear Restorat. Manage. 5, 312–321.
Techera, E.J., Klein, N., 2013. The role of law in shark-based eco-tourism: lessons from Australia. Mar. Policy 39, 21–28.
The International Shark Attack File. The University of Florida, Florida, USA. 2013. <http://www.flmnh.ufl.edu/fish/sharks/isaf/isaf.htm>.
Tisdell, C., Wilson, C., 2001. Wildlife-based tourism and increased support for nature conservation financially and otherwise: evidence from sea turtle ecotourism at Mon Repos. Tourism Econ. 7, 233–249.
Topelko, K.N., Dearden, P., 2005. The shark watching industry and its potential contribution to shark conservation. J. Ecotourism 4, 108–128.
Towner, A.V., Wcisel, M.A., Reisinger, R.R., Edwards, D., Jewell, O.J.D., 2013. Gauging the threat: the first population estimate for white sharks in South Africa using photo identification and automated software. PLoS One 8, e66035. http://dx.doi.org/10.1371/journal.pone.0066035.
UNWTO, 2002. The British ecotourism market. World Tourism Organisation. Available at: <http://pub.unwto.org/WebRoot/Store/Shops/Infoshop/Products/1223/1223-1.pdf>.
Valentine, P.S., 1993. Ecotourism and nature conservation: a definition with some recent developments in Micronesia. Tourism Manage. 14, 107–115.
Velando, A., Munilla, I., 2011. Disturbance to a foraging seabird by sea-based tourism: Implications for reserve management in marine protected areas. Biol. Conserv. 144, 1167–1174. http://dx.doi.org/10.1016/j.biocon.2011.01.004.
Vianna, G.M.S., Meekan, M.G., Pannell, D., Sykes, H., Meeuwig, J.J., 2011. The Socio-economic Value of the Shark-diving Industry in Fiji. Australian Institute of Marine Science, University of Western Australia, Perth, p. 26.
Vianna, G.M.S., Meekan, M.G., Pannell, D.J., Marsh, S.P., Meeuwig, J.J., 2012. Socio-economic value and community benefits from shark-diving tourism

in Palau: a sustainable use of reef shark populations. Biol. Conserv. 145, 267–277.
Vianna, G.M.S., Meekan, M.G., Pannell, D.J., Marsh, S.P., Meeuwig, J.J., 2013. Valuing individual animals through tourism: science or speculation? – Reply to Catlin et al. (2013). Biol. Conserv. 166, 301–302.
Vianna, G.M.S., Meekan, M.G., Bornovski, T.H., Meeuwig, J.J., 2014. Acoustic telemetry validates a citizen science approach for monitoring sharks on coral reefs. PLoS One 9, e95565.
Vignon, M., Sasal, P., Johnson, R.L., Galzin, R., 2010. Impact of shark-feeding tourism on surrounding fish populations off Moorea Island (French Polynesia). Mar. Freshwater Res. 61, 163–169.
Walpole, M.J., 2001. Feeding dragons in Komodo National Park: a tourism tool with conservation complications. Anim. Conserv. 4, 67–73.
Walpole, M.J., Leader-Williams, N., 2002. Tourism and flagship species in conservation. Biodivers. Conserv. 11, 543–547.
Walpole, M.J., Goodwin, H.J., 2001. Local attitudes towards conservation and tourism around Komodo National Park, Indonesia. Environ. Conserv. 28, 160–166. http://dx.doi.org/10.1017/S0376892901000169.
Ward-Paige, C.A., Mora, C., Lotze, H.K., Pattengill-Semmens, C., McClenachan, L., et al., 2010. Large-scale absence of sharks on reefs in the Greater-Caribbean: a footprint of human pressures. PLoS One 5, e11968.
Ward-Paige, C.A., Lotze, H.K., 2011. Assessing the value of recreational divers for censusing elasmobranchs. PLoS One 6, e25609.
Ward-Paige, C.A., Pattengill-Semmens, C., Myers, R.A., Lotze, H.K., 2011. Spatial and temporal trends in yellow stingray abundance: evidence from diver surveys. Environ. Biol. Fish. 90, 263–276.
Wearing, S., Neil, J., 1999. Ecotourism: Impacts, Potentials and Possibilities. Butterworth Heinemann, Oxford, UK, Goodwin and Leader-Williams.
Wunder, S., 2000. Ecotourism and economic incentives—an empirical approach. Ecol. Econ. 32, 465–479. http://dx.doi.org/10.1016/S0921-8009(99)00119-6.
Zacharias, M.A., Roff, J.C., 2001. Use of focal species in marine conservation and management: a review and critique. Aquat. Conserv.: Mar. Freshwater Ecosyst. 11, 59–76.
Ziegler, J., Dearden, P., Rollins, R., 2012. But are tourists satisfied? Importance-performance analysis of the whale shark tourism industry on Isla Holbox, Mexico. Tourism Manage. 33, 692–701.